COMMENT

RAJIT SENGUPTA/CSE

Sunita Narain, director-general of the Centre for Science and Environment in New Delhi, calls for economical waste management.

Priorities for science in India

Ten Indian research leaders give their prescriptions, from better funding, facilities, mentoring and education to greater respect, fairness, autonomy and confidence.

PRADEEP P. MUJUMDAR
Share data on water resources

Professor of civil engineering, Indian Institute of Science, Bangalore

India is facing an imminent water crisis. Almost 100 million people have no access to safe drinking water, and most others experience regular shortages. More than one-third of the roughly 400 rivers that are monitored by the government are polluted.

Groundwater levels are alarmingly low in many areas, owing to overexploitation for irrigation and domestic supply. An estimated 60% of groundwater sources will be degraded in two decades. Cities consume vast amounts of energy to pump water over long distances from rivers and reservoirs, and unplanned urban growth is blocking drainage channels, causing flooding. Climate change will make matters worse. Water availability, demand and quality, as well as floods, droughts and salinity intrusion, will be affected.

But across India, hydrological research is hindered by a lack of access to good-quality data. The government bodies that are custodians of hydrological, meteorological, environmental and agricultural data are reluctant to share information openly. Combined with bureaucratic hurdles, this means that Indian researchers must either use poor-quality data or turn to US or European records.

To strengthen hydrological research and promote scientific decisions on water policy, the government must upgrade its data-collection, monitoring, communication and storage networks, in terms of both technology and density. The government's Water Resources Information System is an excellent start. Now it needs to provide real-time data on stream flow, soil moisture, groundwater levels and evapotranspiration.

'Critical zone observatories' that measure atmospheric, hydrological, biogeochemical, ecological and other fluxes in Earth's near-surface zone should be set up in each of India's seven hydro-climatic regions and ▶

integrated with others globally. Observatories should span different types of climate, terrain, demography, land use and land cover.

India needs multidisciplinary centres of excellence to address big questions — on water-system response rates to climate change, coupled forecasting of intense precipitation and floods, medium-range weather forecasts for agricultural water management and water contamination. These centres would also train the next generation of researchers to use holistic approaches. The Indian Institute of Science, Bangalore, has established such a centre this year. This step should be emulated nationwide with funding from government and private industry.

HIRIYAKKANAVAR ILA
Support the bulk of students

Professor of chemistry, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore

India's university system is broken. The higher-education system was started by the British in 1857 with the establishment of three universities — Calcutta, Bombay and Madras — and 28 affiliated colleges. After independence in 1947 and the creation of the University Grants Commission (UGC) in 1956, the number of universities grew exponentially. Today, there are more than 600, including about 200 private ones. Of the public universities, 46 are funded by central government the rest by state governments. A few, such as the central University of Hyderabad, do world-class research.

In addition to these, to improve training in basic sciences and technology, the government established 16 Indian Institutes of Technology and 5 Indian Institutes of Science Education and Research. There are also about 40 Council of Scientific and Industrial Research laboratories engaged in applied research, along with a few premiere research institutes, including my own.

The handful of these that compete at the international level contribute the bulk of high-quality scientific research in India. But they educate a tiny fraction of our students.

Facilities and teaching at the universities that serve more than 29 million students are alarming. Most are 'chalk and talk' classrooms with poor-quality teaching laboratories, let alone research laboratories. Faculty appointments are often made on the basis of political connections, caste or bribes, and funds are misappropriated. Inbreeding results: many highly qualified young scientists refuse to take up faculty positions in these universities because of the lack of infrastructure, the hostile environment and bureaucracy.

This is a disturbing situation. India needs trained, innovative minds to meet its formidable challenges. The state and central governments should take urgent action.

The government should appoint highly qualified, broad-minded vice-chancellors, who will recruit qualified faculty members and give them state-of-the-art research facilities with no external interference. Faculty should then focus on basic research and quality teaching, and encourage regional and international collaboration networks to strengthen scientific research. The government should also create many specialized research centres in the universities (like the CNRS in France). Fixing our university system will require a complete overhaul of the UGC, changes in institutional policy and legislation. This will be difficult with the present disconnect between science and policy in a government that has cut research budgets, focused on manufacturing and dissolved its scientific advisory committee.

YAMUNA KRISHNAN
Crack the cliques, enable visionaries

Professor of chemistry, University of Chicago, Illinois

To catapult India into the top five scientific nations, the country needs enabling policies that money can't buy. India has huge positives but it is hamstrung by socio-cultural issues, two of which I address here: a herd mentality and a paucity of early-stage mentorship. My ideas stem from my 15 years as a graduate student and young research-group leader in India.

Having recently moved from the National Centre for Biological Sciences in Bangalore to Chicago, Illinois, I have noticed a fundamental difference in the attitude of young US scientists from that of their Indian counterparts: their appetite for big problems.

"The country needs enabling policies that money can't buy."

'Going for great' is a skill acquired very early on in the West. Senior researchers spot gifted graduate students, connect them with the best scientific mentors, nurture them and ensure their visibility over decades.

In India, researchers generally start being mentored only when they show promise as young principal investigators. Thus a fresh returnee from a leading postdoctoral lab abroad suddenly becomes essentially invisible to key collaborators or contacts at home and elsewhere. This results in the returnee pursuing quality problems fragmented into smaller stories for more publications, but of lower visibility. The strategy is to edge slowly towards the big ideas. Often, these big ideas are either suddenly solved by counterparts in the West, or become outdated. A top-down, merit-based, long-term mentorship scheme — starting at the graduate-student stage — could prove transformative.

Cultivating excellence is a selective process that can be perceived as elitist. But India is trying its best to become an egalitarian society. It has some outstanding senior scientists — visionaries who care deeply about taking their nation from good to great. But their efforts are neutralized by a pedestrian majority intent on preserving the status quo.

Instead, these visionaries need to be empowered to take the tough decisions to make Indian science a meritocracy. We must take a census of researchers in all disciplines. Then, preserve scientists with research programmes of international standing, regardless of age, solely on the basis of performance during the past five years. Give them abundant support to ratchet up their programmes. Identify experienced scientists who could each nurture and mentor 5–10 emerging scientists and bring them up to an outstanding level. From such a platform, break open the moribund coteries that hold the system to ransom without themselves doing cutting-edge research. If this can be done, India will soon emerge as a scientific superpower.

I still bubble with optimism. India allows young people with the right attitude to thrive. The nation's history has many examples of the conscience of the majority successfully rejecting deeply embedded socio-cultural mindsets.

JOYASHREE ROY
Train more energy economists

Professor of economics, Jadavpur University, Kolkata

The energy sector will drive India's economic growth for the next three decades. Better access to electricity and cleaner fuel sources will enhance the population's health and well-being and boost industry. But the country faces major challenges, from implementing technologies on the ground to staying within global carbon-emissions limits while ensuring energy access for all.

The discussion so far is one-sided. In India, energy is seen mainly as a science-and-technology issue. There is money for developing microgrids and distributed power devices. But no serious research is being funded to examine the

A man cleans oil barrels for recycling in Dharavi, one of Mumbai's largest and oldest slums.

JONAS BENDIKSEN/MAGNUM

socio-economic impacts and influences.

How will distributed generation affect energy prices and social dynamics? What will happen when new actors such as suppliers of low-carbon energy and 'producer–consumers' enter the fray? Is there an optimum path — environmentally, socially and economically — for depleting natural resources?

India needs more energy economists. Energy has long been seen as an unfashionable topic in the country's universities, and few researchers specialize in the field compared with agriculture, trade, finance and the environment. India must create a forum of energy economists who can discuss and compare the models used to develop energy strategies and influence policy dialogues while understanding local nuances.

India is diverse, and political contexts matter. The energy sector, which meets basic service needs, is susceptible to partisan politics. But scientists have become distanced from policy-makers. Economists need to fill the gap by analysing which governance structures and regional cooperations might emerge under different energy-distribution scenarios and technological options.

A strategy to train the next generation of Indian energy economists could follow the model of the capacity-building programme for environmental economists, which ran from 1998 to 2003 through many participating universities and institutes, funded by the World Bank in collaboration with the then Ministry of Environment and Forests. Similar efforts are now being made by SANDEE, the South Asian Network for Development and Environmental Economics. Academics from around the world helped to train faculties in environmental economics, library content was improved, and grants and fellowships were offered so that Indian researchers could train overseas and build case studies in India.

Today, almost all universities in India have a well-defined, internationally comparable syllabus in environmental economics that is taught by well-trained teachers to plenty of students. It is now mandatory that an environmental economist be a member of each state's environmental impact assessment board. A similar approach for energy economics, starting with interested institutes, would encourage more researchers to seek solutions to India's energy problems.

RAGHAVENDRA GADAGKAR

Solve local problems

Professor of ecology, Indian Institute of Science, Bangalore; and president, Indian National Science Academy

Indian science suffers, today more than ever, from government apathy. This is exacerbated by the fact that India tries to run on the same track as the most developed countries and the best endowed institutes in the world. Only a handful of scientists and institutions in India can afford it, and then only by sequestering an unfair share of the country's scant funds. Even these players barely compete with their chosen peers — never really at the top, but in the 'also ran' category at best. This leaves most researchers and institutions with inadequate resources, and worse, feeling backward.

This is not the only model for success. If you cannot compete on the same track, you should try a different one. India should celebrate and encourage scientists who create their own research questions long before others make the topics fashionable, or those who bring different perspectives to existing problems. Most importantly, we should garland those who work on problems that are crucial to local contexts — even if they are of little interest to elite overseas universities or to 'high-impact' journals. Examples include endemic communicable diseases, groundwater contamination and traditional methods of biodiversity conservation.

India's systems for peer review, grants, publications, jobs, awards and fellowships punish any potential future leaders in such 'unsexy' fields. Instead, the country should develop new scientific ethics and etiquette. The research community should value, for instance, collaboration with small neighbouring colleges or universities instead of recognizing only international alliances. India should create a new peer-review system, a new ranking of journals and new measures of impact — all tailor-made for our needs, problems, diseases, natural resources and educational system. We need to believe in ourselves and not just chase world rankings — as individuals, as institutions and as a country. The enemy is within. So is the solution.

VINOD SINGH

Improve tertiary education

Director, Indian Institute of Science Education and Research, Bhopal

India produces around 9,000 PhD graduates a year in science and technology. This number sounds large, but for a population of about 1.3 billion it is not: the United States produces four times as many from a population one-quarter of the size. Moreover, the variation in quality of Indian PhD graduates and faculty members is a prime concern.

For India to be at the forefront of science and technology we need better governance systems for universities, institutes and research labs. We need more capable academics to provide leadership, nurture young talent and establish a superior research enterprise.

Indian universities are mired in bureaucracy. Archaic ordinances and rules set by the University Grants Commission have stifled the spirit of academic excellence and hampered institutions' flexibility. A lack of passionate leadership coupled with poor funding has blunted their edge.

Leading the way are premier government-funded centres such as the 16 Indian Institutes of Technology, the Indian Institute of Science in Bangalore, the Tata Institute for Fundamental Research in Mumbai, and the 5 Indian Institutes for Science Education and Research. These have one academic

director, who reports to a board of governors of eminent academics, researchers and industrialists. An effective leader — with excellent research and administration skills — can cut through bureaucracy. Other public universities should similarly be made autonomous.

Centrally funded laboratories, tasked with industrially relevant research, should be run along similar lines and integrated with nearby universities and institutes. This would strengthen applied and interdisciplinary research.

In 2009, the Science Engineering Research Board was created to make government science funding quicker and fairer. Its performance now needs to be benchmarked against overseas granting agencies such as the US National Science Foundation.

Quality-control mechanisms must be established for the national accreditation and assessment of Indian PhDs and to improve research and educational training. Doctoral fellowships and research funds should be created in areas of national priority, including food security, energy and the environment. It is high time that India fixed its tertiary education system.

UMESH VARSHNEY

Make science an attractive career

Professor and chairman, Department of Microbiology and Cell Biology, Indian Institute of Science, Bangalore

Is there a dearth of talent in India? Certainly not. Is there a dearth of unstoppable achievers and innovators? Yes: because making talent shine takes a culture that is proud of its scientists and a charged intellectual environment that nurtures, mentors and drives them. The efforts made by a handful of educational institutions, academies and a few others are crucial — but inadequate. We must halt the deterioration in higher-education standards in hundreds of universities, which train and produce huge numbers of science undergraduates and graduates.

Science graduates are deprived of meaningful practical training because of poor funding, government interference, inappropriately recruited faculty members and a lack of laboratory facilities in most of these centres of learning. At this crucial stage in their careers, students are missing out on the mentoring required to instil the culture of science and the habit of analytical thinking and questioning. And once scientists are trained? They work with inadequate, ill-maintained equipment, and in isolation from stimulating peers, being so few in number and so geographically dispersed.

It is imperative that the universities that produce the largest numbers of science graduates are revived so as to be capable of contemporary research. The process can be difficult and slow, or expensive and experimental. One such experiment would be to fund science generously. Another related one would be to pay researchers enough to make science a socially acceptable profession.

Meanwhile, the resilient among us must continue by *jugaad* — the characteristically Indian technique of making do — to try to maintain the scientific base that exists. If only the management of science were left to scientists, India could put its research on the world map — just as it put the Mangalyaan probe into orbit around Mars.

The daily delivery of drinking water causes frenzy in Delhi.

JONAS BENDIKSEN/MAGNUM PHOTO

KRISHNA N. GANESH

Connect research with education

Director, Indian Institute of Science Education and Research, Pune

Historically in the Indian education system, faculty members who teach undergraduates do not do research, and those involved in research (in national laboratories and universities) do not teach undergrads. This is the opposite of the conventional Western university system.

To inject research-led undergraduate teaching, five Indian Institutes of Science Education and Research (IISERs) were set up between 2006 and 2008, in Pune, Kolkata, Mohali, Bhopal and Thiruvananthapuram; the sixth one is being established this year in Tirupati. At the IISERs, students are exposed to research early in their careers, in state-of-the-art labs. Customized curricula connect theory taught in the classroom with lab experiments. Courses in social sciences, ethics and science communication round out the education.

This alliance of education and research catapulted the IISERs to fourth place in India in the 2014 Nature Index, which ranks institutes' outputs — no mean feat for institutes less than a decade old. Together, the IISERs now have 350 faculty members and 3,500 students and will reach their final capacities (2,000 students and 200 faculty members per institute) by 2019.

However, Indian research institutes still fare poorly in global rankings in terms of publication quality. They must try to attract international visiting faculty members and research students, and establish good ties with industry. More than 60% of the 600 students who have already graduated from the IISER system have secured PhD positions in leading universities abroad.

This sort of brain drain is why the Indian system is seriously afflicted by a lack of postdoctoral fellows, who are the engine of the research enterprise elsewhere. Even the best professors in India depend mainly on PhD students for their research. The government's proposed fellowship plan to send Indian PhD holders abroad to gain experience and training in emerging areas should be converted to a programme that 'twins' Indian institutions with foreign research centres, with candidates spending half their time in India. Fellowships could also be opened to foreign nationals wishing to work in India. To assure career progression, these should dovetail into existing tenure-track systems — such as the INSPIRE Faculty Scheme, the University Grants Commission Faculty

Recharge Programme and the Ramanujan and Ramalingaswami fellowships.

To retain or attract back our best young scientists, and entice industry investments, India must create advanced research facilities and assured and scalable research funding, and must foster supportive mentors and visionary institutional leaders. To realize all this, the highest-achieving institutions must be granted immunity from general budget cuts and endowed with 20–30% more in funding for the next ten years, in autonomously controlled budgets. Germany's Max Planck Institutes provide an ideal governing model.

This year has seen cuts in the proportion of gross domestic product spent on science and technology, from an already low starting point of 0.9%. This risks not only undoing the progress achieved, but also doing irreversible damage. At the same time, many important scientific agencies including the Department of Science and Technology (until recently), the Council of Scientific and Industrial Research, the Indian Council of Medical Research and several national laboratories have been without chiefs for more than a year, which has stalled strategic decision-making and dented morale.

In the absence of the Science Advisory Council to the Prime Minister, there is no channel for enlightening the government on the crucial role that scientists could have in addressing India's growing challenges in energy, health, environment, water and education. The country's science academies must build such a bridge. India has a vast supply of talented young people; it is our duty to nurture and harness their talent for a better tomorrow.

SUNITA NARAIN

Manage waste frugally

Director-general, Centre for Science and Environment, New Delhi

India has a huge waste problem. Untreated sewage is defiling rivers and water bodies; industrial chemicals such as cadmium and nitrates are seeping into the ground and polluting the air; and solid waste from kitchen scraps and plastic packaging is piling up in our cities. The problem requires more than management. We need innovative and realistic solutions that match our pockets and our regulatory and governance abilities.

Take sewage. Flushing excreta down toilets is expensive and resource intensive. It uses water as both the carrier and the final dumping point. This approach works in countries that have the means to build huge water-supply and retrieval infrastructures and to pay for maintenance and upgrades of technologies to manage and treat pollutants — from biological waste to toxins. It does not work in India, where there are limited funds for supplying essential services to more than one billion people. A country that is poor — but fast becoming richer and more wasteful — needs a whole new paradigm.

The key obstacle is that everyday challenges are not top priorities for research and innovation. Indian science has always been fascinated by the 'masculine' agendas of space and genetics, not reinventing the toilet.

Instead, science must meet the needs of poor people. We need to devise ways to prevent pollution rather than cleaning it up afterwards. Indian research has to be more humble, nimble and investigative. It has to learn from its poorest and most illiterate people: how they cope with scarce and diverse resources by being frugal and in tune with their environment.

India's ambition should be to become the front-runner in the race to save the planet.

TIFR

Naba Mondal, director of the India-based Neutrino Observatory project.

NABA K. MONDAL

Build big physics facilities

Senior professor, Tata Institute of Fundamental Research, Mumbai

India has an illustrious history in high-energy physics. But two factors make me worry that it will struggle to maintain its position: a shortage of instrument builders and the difficulty of getting planning permission for big facilities.

Technological advances lie behind breakthroughs in particle physics. Indian scientists' enthusiasm and skill for building particle detectors put them at the forefront of the field early on. In the 1950s and 1960s, Indian physicists pioneered experiments with cosmic rays, and developed cloud chambers for use at high altitude. The first published detection of atmospheric neutrinos was made in 1965 with an instrument installed in a mine at Kolar Gold Fields (KGF) in Karnataka state. The first dedicated experiment to study proton decay was carried out at KGF in the early 1980s.

Today, there is little enthusiasm among India's young researchers for building instruments. One reason is that the pay-off is years in the making: researchers lose out in terms of publications compared to peers working in the lab or doing theoretical research. They find it difficult to compete in the academic job market.

Unless we devise metrics that recognize instrument development and retain these skills, it will be difficult to host high-energy-physics experiments in India. India's participation in international projects will be limited to data analysis, making us unequal partners.

Another obstacle is the slow and complex approval procedures for large experimental programmes in India. This is compounded by widespread opposition to large-scale projects by political opportunists and activists on flimsy grounds. In a healthy democracy, meaningful debates are welcome. In India, they are increasingly becoming indiscriminate and adversarial.

For example, controversy has broken out over the proposed India-based Neutrino Observatory, an underground lab in Tamil Nadu for research on neutrinos and related particle physics. The project, of which I am director, received government approval in December 2014. To stay globally competitive, it needs to be up and running by 2020. But we are far from breaking ground. By spreading fictitious fears about neutrinos, a small local political party and a handful of activists have sowed doubts in the minds of local people and made it extremely hard for us to get the required planning permissions.

Unless scientists speak up collectively, it will be prohibitively difficult to develop major science infrastructure in India. ■